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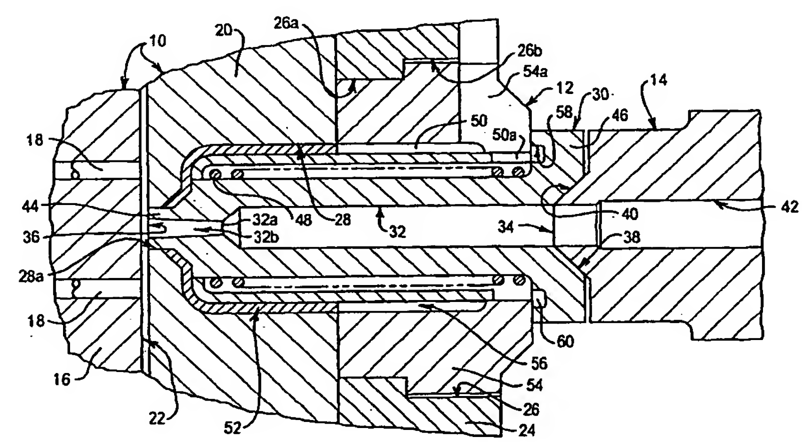
(54) Title: DEVICE FOR HIGH PRESSURE CASTING



(57) Abstract: A device for use in a hot delivery pressure casting machine for pressure casting of a light alloy includes a hollow housing (30) which, from an inlet end to an outlet of the device, defines a bore (32) for forming at least a part of the length of a metal flow path for the flow of alloy from the outlet (14) of an alloy supply source of the machine to a die cavity defined by a mould or die of the machine. The housing (30), at the inlet end thereof, is adapted to receive the outlet (14) of the alloy supply source and, at the outlet end thereof, a relatively short portion of the housing is adapted to be neatly received in an opening defined by a cover portion of the mould or die, whereby the bore (32) of the housing enables communication between the supply source and the die cavity. The device further includes an electric resistance coil (48), disposed around the housing along a major part of the housing from adjacent the inlet end to the outlet end and connectable to an electric power source, and insulating means (52) around the coil (48) for reducing dissipation of heat energy from the housing and coil (48) and providing control of the heat energy level of the housing and the temperature of alloy flowing through the bore (32).

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DEVICE FOR HIGH PRESSURE CASTING

Field of the Invention

This invention relates to a device for use in pressure casting of light alloys.

Background of the Invention

In International patent application WO99/28065 (PCT/AU98/00987), we have disclosed a metal flow system and a process for the pressure casting of magnesium alloys. A related invention for pressure casting of aluminium alloys is disclosed in our co-pending International patent application PCT/AU01/01058, filed on 24 August 2001 and claiming priority from Australian provisional patent application PQ9678 filed on 25 August 2000. The disclosure of each of these applications is incorporated herein by reference, to enable a full understanding of the background to the present invention.

Each of the applications WO99/28065, PCT/AU01/01058 and PQ9678 proposes the use of a metal flow path which departs significantly from established practices for the pressure casting of magnesium and aluminium alloys, respectively. In each case, the proposal is for use of at least one runner which is small in cross-sectional area for a given casting compared with runners used in the established practices. Also, the or each runner communicates with a die cavity though what is referred to in WO99/28054 and PQ9678 as a controlled expansion region or point but which, in the preferred terminology of application PCT/AU01/01058, is referred to as a controlled expansion port or CEP. In contrast to gate arrangements used in the established practices, a CEP has an exit into the die cavity which has a larger cross-sectional area than the runner. Also, the proposal is for use of metal flow velocities through the runner and CEP which are high relative to those used in the established practices, while the ratio relationship between the runner and CEP metal flow velocities is the converse of the relationship between the runner and gate flow velocities required in the established practices. That is, the metal flow velocity at the CEP exit is less than the runner flow velocity, whereas the established practices is for a gate flow velocity which is higher than the runner flow velocity.

The proposals of applications WO99/28065, PCT/AU01/01058 and PQ9678 enable a number of significant, practical benefits to be obtained in the pressure casting of magnesium and aluminium alloys, respectively. One of

these is a very substantial reduction in the ratio of runner metal weight to product weight compared to the ratio obtaining with the current practices, particularly as the length of the metal flow path can be relatively short in use of those proposals. As a consequence of this reduction, the inventory of alloy required can be substantially reduced. Also, there is a substantial reduction in the energy level required for melting alloy which, after casting, needs to be recovered and recycled. As will be appreciated, the reduction of recycled alloy is of particular benefit in casting magnesium alloys, given the reprocessing requirements for magnesium alloys. Moreover, the proposals enable a significant reduction in the tonnage of alloy poured in producing a given tonnage of product, with a corresponding reduction in the loss of alloy.

In use of the proposals of applications WO99/28065, PCT/AU01/01058 and PQ9678, cast products are at least comparable in quality to those obtained with the established practices. However, with use of the proposals for maximum benefit, components of the mould or die defining the metal flow path from the supply to the die cavity are quite compact. As a consequence, there can be difficulty in controlling solidification back from the die cavity to a controlled solid/liquid interface location. This difficulty exists particularly with the use of magnesium alloys.

Magnesium alloys have a low heat of fusion and high thermal conductivity. They therefore are easily solidified and difficult to maintain liquid. Also, over a significant temperature range below the solidus point, magnesium alloys have a low fracture strength. As a consequence, solidification of runner metal which is to separate with a casting can proceed back too far, with the risk of solid metal fracturing and leaving a plug of solid metal in the CEP or in the runner. This risk is increased by the small CEP and runner cross-sections used in the proposals of applications WO99/28065, PCT/AU01/01058 and PQ9678, and the high heat capacity of the mould or die compared with alloy in the runner.

<u>Summary of the Invention</u>

The present invention provides a device for use in at least reducing the problem experienced in pressure casting of magnesium alloys. However the device also has utility in pressure casting of other light alloys, such as aluminium alloys.

According to the present invention, there is provided a device for use in a hot delivery pressure casting machine for pressure casting of a light alloy. The device includes a hollow housing which, from an inlet to an outlet at respective ends of the device, defines a bore for forming at least a part of the length of a metal flow path for the supply of alloy from an outlet of an alloy supply source, such as a supply nozzle, of the machine to a die cavity defined by a mould or die of the machine. At the inlet, the housing is adapted to receive the outlet of the supply source or nozzle for providing communication between the supply source and the bore. At the outlet end, a relatively short portion of the housing is adapted to be neatly received in an opening defined by a cover portion of the mould or die for providing communication between the bore and the die cavity. The device further includes an electric resistance coil disposed around the housing and connectable to electric power source, with the coil extending along a major part of the housing, from adjacent to the inlet end and towards the outlet end. Around the coil, the device further includes insulating means, such as a heat shield and/or thermal insulation, for reducing dissipation of heat energy from the housing and coil such as, in use, to adjacent portions of the mould and substantially to thermally isolate at least a main part of the housing from the adjacent portions of the mould.

Thus according to the invention, there is provided a device for use in a hot delivery pressure casting machine for pressure casting of a light alloy, wherein the device includes a hollow housing which, from an inlet end to an outlet end of the device, defines a bore for forming at least a part of the length of a metal flow path for the flow of alloy from the outlet of an alloy supply source of the machine to a die cavity defined by a mould or die of the machine; the housing, at the inlet end thereof, is adapted to receive the outlet of the alloy supply source and, at the outlet end thereof, a relatively short portion of the housing is adapted to be neatly received in an opening defined by a cover portion of the mould or die, whereby the bore of the housing enables communication between the supply source and the die cavity; and wherein the device further includes an electric resistance coil, disposed around the housing along a major part of the housing from adjacent the inlet end to the outlet end and connectable to an electric power source, and insulating means around the coil for reducing dissipation of heat energy from the housing and coil and

providing control of the heat energy level of the housing and the temperature of alloy flowing through the bore.

At least in use of some forms of the invention, the bore may provide direct communication with the die cavity. In such forms, the bore is runner-like in its function and, hence, equivalent to a runner. However it does not conform to normal usage of the term "runner". Accordingly, it is referred to throughout this disclosure as a bore, even though it meets the requirements of the proposals of applications WO99/28065, PCT/AU01/01058 and PQ9678 for a runner. In such forms in which the bore is runner-like in its function and provides direct communication with the die cavity, the bore has a second part of its length ending at the outlet which increases in cross-section such that the outlet has a larger cross-section than the preferably substantially constant cross-section for a first part of the length of the bore extending from adjacent to the inlet. That is, the bore may have inlet and outlet end portions of its length, with the outlet end portion increasing in cross-sectional area to the outlet end from a minimum area defined by inlet end portion whereby the outlet end portion of the bore defines a controlled expansion port (or CEP) enabling use of the device for direct injection into a die cavity. Thus, the part of the length of the bore ending at the outlet conforms to requirements for a CEP.

The hollow housing may be of elongate form. This is preferred for ease of fabrication, but other forms can be adopted, such as to suit the arrangement of a given machine. The housing preferably is of circular cross-section, as preferably is the bore, again for ease of fabrication. Also, the housing preferably is of a high temperature steel, such as H13, but other suitable metals or refractory materials, or combination of a metal and refractory material, can be used.

The inlet of the housing preferably defines a seat, such as a recessed seat, of a shape which is complementary to the form of the outlet end of the alloy supply source or nozzle it is adapted to receive. The seat may be part spherical or of similar concave or convex form, or it may be of frusto-conical or other suitable form. In any event, for a given supply source outlet end or nozzle, the seat is required to provide good surface to surface contact with the outlet end of the supply source or nozzle, to enable substantially leak-free flow of molten alloy from the nozzle to the bore.

The device may be mounted in relation to a mould or die with which it is designed to be used by inserting the housing into a the opening or recess defined by the mould cover portion so as to position the outlet of the housing at a required location adjacent to the die cavity. Thus, at or towards the inlet, the housing may have means engageable with the mould cover portion, or with a platen on which the cover portion is mounted, when the housing outlet is at the required location. In one arrangement, the housing may have adjacent to the inlet a peripheral flange, or other laterally extending abutment, by which it is adapted to bear against an external surface of the cover portion or platen when the housing has been fully inserted to position the housing outlet at such location. In an alternative arrangement, the housing may have such flange or abutment, and a sleeve concentrically around the housing and against which the flange or abutment bears, with the sleeve being engageable in the cover portion or platen to a predetermined depth to thereby position the housing outlet at the required location.

Where a sleeve is provided in the above-mentioned alternative arrangement, the sleeve may have an end face, remote from the inlet, by which it bears against a reference surface of the mould cover portion or platen. The sleeve also may have a peripheral surface by which it is able to securely engage with the cover portion or platen, such as by a friction fit and/or by screw threaded engagement therewith.

In one embodiment the resistance coil and insulating means comprising a heat shield each extends around the housing along at least part of the length of the bore. Where the housing has a flange or lateral abutment adjacent to the inlet, each of the coil and heat shield may extend from adjacent the housing outlet to the engagement means, such as a flange or abutment. Where there is a sleeve against which the flange or abutment bears, the sleeve may define an annular air-gap around the heat shield to minimise thermal contact between the sleeve and each of the housing and heat shield. Such contact may be limited to a part of the sleeve adjacent to the flange or abutment. Also, a surface of flange or abutment which bears against the sleeve may be recessed to minimise thermal contact therebetween.

In a further embodiment, the resistance coil and insulating means comprising thermal insulation each extends around the housing along at least

part of the length of the bore. In such case, the insulation may be retained around the housing and the resistance coil by an elongate bush through which the housing extends. The bush, at one end, may terminate at an end portion of the housing which defines the outlet and by which the housing is adapted to be neatly received in the opening defined by the cover portion of the mould. At its other end, the bush may terminate at an end portion of the housing which defines the inlet. Beyond the other end of the bush, the housing may form a tapered plug on which a frusto-conical outlet of the supply source or nozzle is able to seat to enable the flow of alloy from the supply source or nozzle, along the bore of the housing.

The heating of the housing by the resistance coil may be augmented, in use, by heating a the outlet end of the supply source or nozzle in communication with the inlet of the housing, and this heating may, for example, be by flame heating. A heat shield extending outwardly around the housing may be provided to protect the mould cover portion or platen from such augmenting heating.

The heat shield, in each of the forms described, may be of a suitable metal, such as mild steel. The thermal insulation can be of any suitable material. Fibrous thermal insulation, such as alumina borosilicate, is suitable.

The bore defined by the housing may communicate with the die cavity through a CEP also defined by the housing. In such case, the outlet end of the CEP most preferably comprises the outlet of the housing, such that the device is adapted for direct feed of alloy to the die cavity. However, in an alternative arrangement providing for indirect feed of alloy to the die cavity, the bore defined by the housing may end at the outlet. In such alternative, at least one runner, which receives alloy from the device, will be defined by the mould or die and provide part of the overall metal flow path. Thus, alloy flow from the device to the die cavity, or to each of a plurality of die cavities, is via at least one runner. The or each runner or its die cavity preferably defines a CEP.

With the supply of electric power to the resistance coil, the device of the invention enables a heat energy balance to be maintained. The balance may be such that, on solidification of cast metal back to the outlet of the housing and into the bore, the location of a solid/liquid interface in the bore is able to be at a required location adjacent to the outlet. Also, a high thermal gradient across the

interface is able to be achieved whereby, even with casting of magnesium alloys, solidified metal in the bore is able to be fully extracted on release of a casting from the die cavity. That is, rupturing of solidified metal in the bore is able to be avoided, obviating the problem of a slug of solidified metal being left behind.

The heat energy balance and high thermal gradient are able to be achieved by:

(a) the heating maintaining the housing at a suitable elevated temperature; and

(b) heat energy loss from the housing to the mould being minimised and controlled, with substantially the only metal to metal good thermal contact between the housing and the mould being limited to the relatively short portion of the housing at the outlet which is neatly received in an opening defined by a cover portion of the mould.

However, these factors can be assisted by that relatively short portion being of reduced wall thickness and by the bore therein increasing in diameter to the outlet. The reduced wall thickness enables that portion to be cooled by the mould cover portion, while the increasing diameter enables extraction with a casting of alloy solidified therein. As detailed above, the end portion of the bore of increasing diameter to the outlet may define a CEP, although this is not necessarily the case.

The invention also provides a hot delivery pressure casting machine having a mould defining a die cavity and means for supplying alloy to be cast to the die cavity, wherein the supply means includes a device according to the invention which is mounted in relation to the mould whereby the bore defined by the housing forms part of the length of a metal flow path for the supply of alloy to the die cavity.

In one form, the invention provides a hot delivery pressure casting machine, for pressure casting of a light alloy, wherein the machine includes a mould or die defining a die cavity, a supply means for supplying alloy and a device located intermediate the supply means and the die or mould; the device includes a hollow housing which, from an inlet end to an outlet end of the device, defines a bore forming at least a part of the length of a metal flow path for the flow of alloy from the outlet of the alloy supply means to the die cavity;

the housing, at the inlet end thereof, is coupled to the outlet of the alloy supply source and, at the outlet end thereof, a relatively short portion of the housing is neatly received in an opening defined by a cover portion of the mould or die, whereby the bore of the housing provides communication between the supply source and the die cavity; and wherein the device further includes an electric resistance coil, disposed around the housing along a major part of the housing from adjacent the inlet end to the outlet end and connectable to an electric power source, and insulating means around the coil for reducing dissipation of heat energy from the housing and coil and providing control of the heat energy level of the housing and the temperature of alloy flowing through the bore; and wherein the bore has inlet and outlet end portions of its length, with the outlet end portion increasing in cross-sectional area to the outlet end from a minimum area defined at or adjacent to the inlet end portion whereby the outlet end portion of the bore defines a controlled expansion port (or CEP) which increases in cross-sectional area to the outlet end and by which the bore opens to the die cavity whereby the device provides for direct injection of alloy into the die cavity from the CEP with a decreased alloy flow velocity in the CEP relative to its flow velocity in the inlet end portion.

In another form, the invention provides a hot delivery pressure casting machine, for pressure casting of a light alloy, wherein the machine includes a mould or die defining at least one die cavity, a supply means for supplying alloy and a device located intermediate the supply means and the die or mould; the device includes a hollow housing which, from an inlet end to an outlet end of the device, defines a bore forming a first part of the length of a metal flow path for the flow of alloy from the outlet of the alloy supply means to the die cavity; the housing, at the inlet end thereof, is coupled to the outlet of the alloy supply source and, at the outlet end thereof, a relatively short portion of the housing is neatly received in an opening defined by a cover portion of the mould or die, whereby the bore of the housing provides communication between the supply source and the die cavity; wherein the device further includes an electric resistance coil, disposed around the housing along a major part of the housing from adjacent the inlet end to the outlet end and connectable to an electric power source, and insulating means around the coil for reducing dissipation of heat energy from the housing and coil and providing control of the heat energy

level of the housing and the temperature of alloy flowing through the bore; and wherein the bore at an outlet end of the housing opens to a runner forming a second part of the length of the flow path defined by the die or mould, with communication between the runner and the die cavity being provided by a controlled expansion port (or CEP) which increases in cross-sectional area towards the die cavity whereby the flow path provides for indirect injection of alloy into the die cavity from the CEP with a decreased alloy flow rate in the CEP relative to its flow velocity in the runner.

Brief Description of the Drawings

In order that the invention may more readily be understood, reference now is directed to the accompanying drawings, in which:

Figure 1 is a partial sectional view of a mould, showing a first embodiment of a device according to the invention mounted in relation to the mould and the nozzle of a hot chamber die casting machine;

Figure 2 is a sectional view of the housing of the device according to the first embodiment;

Figure 3 is an end elevation of the housing, taken from the left hand end of Figure 2;

Figure 4 is similar to Figure 1, but shows a second embodiment of a device according to the invention; and

Figure 5 again is similar to Figure 1, but shows a third embodiment of a device according to the invention.

Detailed Description of the Drawings

In the arrangement of Figure 1, there is shown a partial section of a mould or die 10, a device 12 according to the present invention, and the outlet end of a nozzle 14 of the goose-neck of a hot chamber die casting machine in relation to which mould 10 is mounted.

The mould 10 includes an ejector portion 16, for which ejector pins 18 are shown, and a cover portion 20. With portions 16,20 closed, as shown, they define a die cavity partly represented at 22. The cover portion 20 is mounted on a platen 24.

The device 12 extends through platen 24 and into mould cover portion 20, to provide communication between nozzle 14 and die cavity 22. For this, platen 24 defines an opening 26 therethrough, while cover portion 20 defines an

opening 28 which provides a smaller diameter continuation of opening 26 through to die cavity 22.

The device 12 includes an elongate tubular housing 30, also shown in Figure 2, which defines a through bore 32 of circular cross-section extending between an inlet 34 and an outlet 36. At the inlet 34, bore 32 is bevelled to define an annular, frusto-conical seat 38 against which a complementary end 40 of nozzle 14 is received to put the passage 42 of nozzle 14 in communication with bore 32. Adjacent the outlet 36, housing 30 has a an end portion 44 which is of reduced external diameter and which is a neat friction fit in the reduced diameter inner end 28a of opening 28. As shown, portion 44 is of substantially reduced wall thickness relative to the main extent of housing 30.

Around housing 30, between its end portion 44 and a peripheral flange 46 defined by housing 30 adjacent inlet 34, device 12 has an electrical resistance coil 48. Around coil 48, device 12 further includes a cylindrical heat shield 50 which extends through opening 26 of platen 24 and into opening 28 for a major part of the thickness of mould cover portion 20. Between inner end 28a of opening 28 and platen 24, device 12 includes a sleeve 52 of thermal insulation over heat shield 50.

Between insulation sleeve 52 and flange 46, device 12 includes an annular bush 54 through which housing 30 and heat shield 50 extend. The bush 54 has a stepped internal surface such that, adjacent flange 46, bush 54 is a neat fit on the adjacent end of shield 50. However, beyond this, bush 54 is spaced from shield 50 to define an insulating air-gap 56. Also, bush 54 and flange 46 abut, with the surface of flange 46 in contact with bush 54 defining an annular groove 58 to provide a further air-gap 60 which reduces loss of heat energy from housing 30 to bush 54.

The external peripheral surface of bush 54 and the opening 26 of platen 24 are of stepped, complementary form. The arrangement is such that, at a reduced diameter inner part 26a of opening 26, bush 54 is a neat fit therein while, at an outer part 26b of opening 26, bush 54 is in screw-threaded engagement with platen 24. Also, with bush 54 fully received into opening 26, it bears against the outer face of mould cover portion 20 such that the end of housing 30 at outlet 36 is flush with the inner face of portion 20 which defines part of die cavity 22.

Exteriorly of platen 24, adjacent flange 46, bush 54 is cut away at 54a while shield 50 is cut away at 50a, to provide an exit for electrical leads (not shown) for resistance coil 48. Such leads are connectable to a suitable power source for providing resistance heating of coil 48 and, hence, heating of housing 30, such that solidification of alloy in bore 32 of housing 30 can be limited to part of the length of bore 32 in portion 44 of housing 30.

Over a major part of its length, from inlet 34, the bore 32 has a cross-sectional area substantially the same as passage 42 of nozzle 14. From that length, the cross-section of bore 32 tapers down to a minimum cross-section at 32a, after which bore 32 has a short portion 32b which progressively tapers outwardly in cross-section to outlet 34.

As will be appreciated, the device 12 provides for direct feed of alloy into die cavity 22. As such, bore 32 functions as a runner, having an effective cross-section corresponding to the minimum at 32a, while the portion 32b is a CEP. Thus, the device provides a flow path for alloy as required by applications WO99/28065 and PQ9678. In a suitable example for the arrangement illustrated, the runner-like bore 32 may have a diameter of about 4 mm at 32a (reducing to this from a larger diameter of about 12 mm), with portion 32b of bore 32 increasing in diameter over a length of about 22 mm to a maximum diameter of about 6 mm at outlet 36. As a consequence, the metal flow velocity at 36 is reduced relative to the effective runner flow velocity at 32a, with each of these velocities being high (due to the indicated diameters at 32a and outlet 36) for a conventional pressure die casting machine, relative to runner and gate velocities in accordance with established practices.

In use of the arrangement of Figure 1, housing 30 is heated by resistance heating of coil 48. However, the effect of this heating is substantially able to be contained to housing 30 and alloy therein, due to the provision of shield 50, insulation sleeve 52, and air-gaps 56 and 60. Thus, except for the portion 44 of housing 30 between sleeve 52 and outlet 36, the scope for heat energy loss to mould cover portion 20 or to platen 24 is minimised. However, if required, heat loss from portion 44 to mould cover portion 20 can be enabled and increased by cooling of cover portion 20 exteriorly of device 12. In any event, heat loss to cover portion 20 through the portion 44 of housing 30 is desirable since, with appropriate heat energy balance, it is possible to regulate

solidification of cast metal back from die cavity 22 into bore 30 so as to consistently locate a solid/liquid interface with a high thermal gradient to a transverse plane through bore 30 which is close to outlet 36. That is, an appropriate heat energy balance is possible which provides a steep thermal gradient for generating a solid/liquid interface at a required location within the CEP, such as adjacent the end of insulation sleeve 52 at portion 44 or slightly nearer to outlet 36. As a consequence, the short length of metal solidified in bore 30 has good fracture strength and it is able to be separated with a product, on completion of casting, without rupturing to leave a plug of solid metal in the larger diameter length of bore 30.

As shown in Figures 2 and 3, housing 30 has a groove 62 formed along a major part of its length from flange 46. From groove 62, a number of recesses 64 are formed in the wall of housing 30. The arrangement is such that thermocouple leads are able to enter through the cut away at 54a and 50a and extend along groove 62, for location of a respective thermocouple in each recess 64. Thus, the temperature of housing 30 is able to be monitored and, as required, the power supply to resistance coil 48 can be varied to increase or decrease the temperature of housing 30.

The arrangement of Figure 4 generally will be understood from the description of Figures 1 to 3. Components shown in Figure 4 which correspond to those of the arrangement of Figures 1 to 3 have the same reference numeral, plus 100. Description largely is limited to features by which the arrangement of Figure 4 differs from features of the arrangement of Figures 1 to 3.

While device 12 of Figures 1 to 3 provides for direct injection of alloy into die cavity 22, device 112 of Figure 4 provides for indirect feed into a respective die cavity 122 (or into respective parts of a single die cavity 122). Thus, from outlet 136, mould 110 defines runners 66, each ending at a CEP 68, through which alloy is able to flow to the, or each, die cavity 122. From outlet 136, each runner 66 has a length formed in ejector portion 116 of mould 110, but then cuts across to cover portion 120 in which its CEP 68 is provided. Each CEP 68 has a depth in portion 120 which is similar to the depth of its runner 66. However, in a plane perpendicular to the section shown in Figure 4, each CEP 68 increases in width to a maximum at its outlet to the die cavity 122.

Device 112 has a heat shield 150 which covers coil 148 around a major part of the length of housing 130. However, device 112 does not include thermal insulation corresponding to sleeve 52 of device 12 of Figures 1 to 3, although provision for such insulation is possible, if required. Also, around shield 150, bush 154 defines a large air gap 156, while gap 156 extends into groove 158 of flange 146 of housing 130.

The bore 132 of housing 130 is of uniform diameter over its length within the resistance coil 148 and provides a continuation of passage 142 of alloy supply source nozzle 114. However, over the short part 132b of its length adjacent to outlet 136, bore 132 increases in diameter to a maximum at outlet 136. However, part 132b of bore 132 does not function as a CEP and, as indicated above, the required CEP's are defined by mould portions 116 and 120, beyond outlet 136.

Operation with the device 112 of Figure 4 is similar to that for the device 12 of Figures 1 to 3, except that device 112 provides indirect feed of alloy to each die cavity 122 (via a respective runner 66). However, again heating is applied by the resistance coil 148. If required, this heating can be supplemented by gas or electric heating of the junction between nozzle 114 and housing 130 (as, indeed, is possible in the arrangement of Figures 1 to 3).

Again, heat loss from housing, in large part, is by the part 144 of housing 130 in metal to metal contact with mould cover portion 120. In this instance, housing 130 is not of significantly reduced wall thickness at part 144. However, it again is possible to achieve a solid/liquid interface with a high thermal gradient in bore part 132b, within the length of part 144. If necessary, this can be assisted by cooling of mould part 116 and/or part 120. Again, the arrangement enables the solid/liquid interface to be produced within part 144 of housing 130, enabling separation of all alloy solidified in bore 132 on release of a cast product.

The arrangement of Figure 5 also largely will be understood from the description of Figures 1 to 3. Components of the arrangement of Figure 5 corresponding to components of that of Figures 1 to 3 have the same reference numeral, plus 200.

Device 212 of Figure 5, as in Figures 1 to 3, provides for direct injection into die cavity 222 defined by mould parts 216 and 220. Thus, portion 232b of bore 232 defined by housing 230 comprises a CEP.

The region of housing 230 around which flat strip resistance coil 248 is provided is cylindrical and has a helical groove 80 in which coil 248 is located. Also, a sleeve 250 of insulation is a close fit over that region of housing 230, and assists in retaining coil 248 in position. Around the insulation sleeve 250, a cylindrical bush 254 is fitted, with the bush providing a neat friction fit in platen 224 as part 244 of housing 230 is received as a neat fit in the inner extent of opening 228 of mould cover portion 220.

Beyond flange 246, housing 230 has a tapered plug 82 over which a frusto-conical seat of nozzle 214 is fitted. Thus, inlet 234 of device 212 is within nozzle 214, and bore 232 of housing 230 provides a continuation of passage 242 of supply nozzle 214. The coupling between housing 230 and nozzle 214 can be electrically or gas heated, to augment heating of housing 230 by resistance coil 248. A heat shield 84 is fitted over plug 82 of housing 230, to protect the mould from such heating of the coupling, with shield 84 being held between flange 246 and bush 254 on one side, and nozzle 214 on the other side, of shield 84.

Operation with device 212 in the arrangement of Figure 5 will be understood from description of Figures 1 to 3 and Figure 4. Again, the arrangement enables the solid/liquid interface to be produced within part 244, with separation of all alloy solidified in bore 232 on release of a cast product. Again the interface, with a high thermal gradient is located within the length of part 244, if necessary with this assisted by cooling or mould part 216 and/or part 220, as represented by coolant flow passage 90 in part 216.

In the arrangement of Figures 1 to 3, the portion 32b of bore 32 increases in cross-sectional area from the minimum at 32a to outlet 36. In the case of Figure 4, portion 132b increases in cross-section from location 132a to outlet 136, although in this instance, bore 132 is of uniform cross-section from inlet 134 to location 132a. The arrangement of Figure 5 for portion 232b of bore 232 is similar to that of Figures 1 to 3, except that portion 232 is somewhat longer in length. As previously indicated for each of devices 12, 112 and 212, solidification of alloy in the respective, or each respective, die cavity proceeds

back along the alloy flow path to a solid/liquid interface within the length of the respective bore portion 32b, 132b, 232b. Thus, on release of a casting, or each casting, the alloy solidified back to that interface separates with the casting(s), with release of solid alloy in the respective bore portion 32b, 132b, 232b being facilitated by its decreasing cross-section back along that bore portion.

In the case of device 12 of Figures 1 to 3 and device 212 of Figure 5, the respective bore portion 32b, 232b is described as being a CEP. This is not the case with bore portion 132b of device 112 of Figure 4, as device 112 provides for indirect injection via a respective runner 66 for each die cavity 122. However, in Figure 4, each runner 66 communicates with its die cavity 122 via a respective CEP 68. As with the respective CEP provided by portion 32b in Figures 1 to 3, and by portion 232b in Figure 5, each CEP 68 increases in cross-sectional area from a minimum cross-section of its runner 66 to a maximum cross-sectional area at its outlet to the respective die cavity 122.

As is well understood, established practice for pressure casting utilises a runner and gate arrangement in which a gate defines an opening from the outlet end of a runner to a die cavity. In such arrangement, the gate is of lesser cross-sectional area than the runner such that alloy flowing into the die cavity has a correspondingly increased flow velocity through the gate relative to its flow velocity through the runner. As a CEP increases in cross-sectional area from its inlet end, at the outlet end of its runner, to its outlet end by which it communicates with its die cavity, it will be appreciated that the converse flow velocity relationship obtains compared with a runner and gate arrangement. That is, the alloy flow velocity through a CEP decreases relative to the flow velocity in its runner, to a minimum flow velocity at the outlet end of the CEP.

As will be appreciated from applications WO99/28054, PCT/AU01/01058 and Australian provisional application PQ9678 (the basic or Convention application for PCT/AU01/01058), the use of a metal flow system incorporating a CEP enables pressure casting in a manner which differs significantly from established practice based on use of a runner and gate arrangement, and provides a number of practical benefits. As is evident from those applications, and as detailed earlier herein, one benefit is a very substantial reduction in the ratio of the weight of runner and associated metal to the weight of finished product, compared to the ratio obtaining with current or established practice.

That is, the weight of cast metal needing to be recycled to the weight of finished product is substantially reduced, with resultant reduction in production costs. While the reduction in production costs is applicable to all pressure casting alloys, it is of particular benefit with magnesium alloys due to the reprocessing requirements for recycling of these alloys. However, a further benefit of a metal flow system incorporating a CEP has particular value for magnesium alloys, in that it facilitates the production of castings of those alloys which have a significantly reduced degree of surface defects, compared with similar castings produced in accordance with established practice, such as to be of a quality comparable to castings of aluminium or zinc alloys obtainable with established practice.

A CEP for a metal flow system having a device according to the present invention preferably is such as to result in an alloy flow velocity at its outlet which is from about 50% to 80%, more preferably from about 65% to 75% of the flow velocity at its inlet and/or in its runner. However, the actual flow velocities vary with the particular alloy being used. For an aluminium alloy, the flow velocity in the runner or at least at the CEP inlet preferably is in excess of 40 m/s to 50 m/s, more preferably in excess of 60 m/s, such as from 80 m/s to 120 m/s, preferably from 80 m/s to 110 m/s. The flow velocity at the outlet of a CEP for an aluminium alloy may be in excess of 20 m/s, preferably in excess of 30 m/s, such as from about 40 m/s to 95 m/s and most preferably from about 40 m/s to 90 m/s. For a magnesium alloy, the flow velocity in the runner or at least at the inlet end of a CEP may be in excess of 50 m/s, such as from about 140 m/s to 165 m/s, with the velocity at the CEP outlet correspondingly reduced as indicated above. For other alloys, such as zinc and copper alloys, the CEP flow velocities may be similar to those for aluminium alloys, although the range can vary with the unique characteristics of individual alloys. In each case, a CEP can be relatively short, such as from 5 mm to 20 mm, preferably from 10 mm to 15 mm. Thus, the residence time for alloy in a CEP is very short, such as from 60 to 100 μs for magnesium alloy flowing through the outlet end of a CEP at a preferred flow velocity.

The device of the invention may define, or form part of, a metal flow system as disclosed in our co-pending Australian provisional application PR7218, entitled "Metal Flow System" filed on 23 August 2001. Also, a CEP

defined within, or of a metal flow system including, a device according to the invention may be in accordance with the disclosure of either of our co-pending Australian provisional applications PR7214 and PR7217, each filed on 23 August 2001 and respectively entitled "Improved Magnesium Alloy Castings" and "Improved Alloy Castings". In each case, the metal flow system enables particularly beneficial results to be achieved in that, by virtue of the CEP, a resultant casting produced using the metal flow system is able to attain a desirable fine microstructure as detailed in each of applications PR7218, PR7214 and PR7217. Such microstructure is one characterised by fine, degenerate dendrite primary particles in a matrix of secondary phase, in which the primary particles are rounded or spheroidal in form, preferably less than 40 μm and most preferably substantially less than 40 μm such as about 10 μm, and evenly distributed substantially throughout the casting. The device of the invention can facilitate attainment of such microstructure, by enabling a required heat energy balance to be maintained. As detailed above, the energy balance facilitates required location of a solid/liquid interface on solidification of cast metal back to the outlet of the device. As a consequence, the die or mould can be cooled sufficiently rapidly so as to retain such microstructure in a solidified casting, without risk of rapid solidification progressing back beyond such location or a risk of premature solidification of alloy in the metal flow system.

In relation to such rapid solidification, it is to be recognised that the cross-sections of a metal flow path defined by, or including, a device according to the invention are small relative to cross-sections of a runner and gate arrangement used in established pressure casting practice. A good heat energy balance therefore is necessary because of a resultant increased risk of premature solidification of alloy in the metal flow system.

A pressure casting machine with which the device of the present invention is able to be used can be of a variety of types. It may, for example, be a hot chamber die casting machine, in which case the nozzle 14 of Figures 1 to 3, or the respective nozzle 114 and 214 of Figures 4 and 5 comprises the outlet end of the gooseneck of such machine. Alternatively, the machine may be a cold chamber die casting machine, with nozzles 14,114 and 214 comprising the outlet end of the shot-sleeve of such machine. In a further alternative, the machine may be of the type disclosed in our co-pending Australian patent

application PR7216, entitled "Apparatus for Pressure Casting" filed on 23 August 2001. The apparatus of application PR7216 utilises a transfer vessel into which a measured volume of alloy sufficient for a single casting cycle is receivable, and from which the alloy is dischargeable by gas pressure applied to the surface of the measured volume to cause the alloy to flow along a metal flow path to a die cavity. The device of the present invention may define, or be included in, the flow path of that apparatus.

With each of hot- and cold-chamber die casting machines and a machine according to application PR7216, molten alloy is supplied to a metal flow path from an alloy supply source of the machine. In its flow through a CEP of the alloy flow path, the flow velocity of the alloy decreases between the inlet and outlet of the CEP as detailed above. At least in preferred forms of a CEP, such as one enabling the attainment of a casting having a microstructure as detailed above, this reduction in flow velocity results in a change in the state of the alloy. This change is from one in which the alloy is relatively highly fluid, and usually substantially free of entrained solids, to one in which the alloy attains a viscous or semi-solid state. The change can be such that the alloy becomes thixotropic whereby, in the thixotropic state, the alloy is able to flow like a liquid under applied force. Due to this, and extreme turbulence generated in the alloy in its flow through the CEP, a high level of nucleation of primary particles is generated, with these particles attaining a degenerate dendrite form which is retained in flow throughout the die cavity. The form of the primary particles and the level of their nucleation is such that the particles are small, generally about 10 μm or less, and rapid solidification of alloy in the mould or die enables the microstructure described above to be retained in a finished casting by suppression of grain growth.

With each arrangement according to the invention, molten alloy received by the device from the machine supply means is able to flow into the die cavity in a viscous or semi-solid state. The alloy in that state preferably is thixotropic such that, under the pressure at which it is supplied, it flows as a liquid. In the viscous or semi-solid, preferably thixotropic state, the alloy flow in the die cavity proceeds on an advancing front, rather than as a jet which passes across the die cavity, away from the inlet to the die cavity. The change in the alloy from a molten state, in which it is highly fluid, to a viscous or semi-solid state, results

from the reduction in flow velocity achieved in the CEP. This obtains whether the CEP is defined by the device, or by a part of the alloy flow path between the outlet of the device and the die cavity.

With each type of machine, a preferred form of CEP for achieving the microstructure as described above is as disclosed in our Australian provisional patent applications PR7214 and PR7217 detailed above. That form of CEP is one which, with operation to produce a casting having that microstructure by rapid solidification of alloy in the die cavity and back along the flow path into the CEP, the metal solidified in the CEP has a specific, somewhat related microstructure. This is a microstructure which, in longitudinal sections through metal solidified in the CEP (i.e. in sections parallel to the flow direction therethrough), exhibits striations or bands which extend transversely of the CEP (i.e. transversely of the flow direction). For magnesium alloys, the striations have a wavelength or spacing between centres of successive like bands of the order of about 40 µm. The spacing for aluminium and at least some other alloys more usually of the order of about 200 µm. Successive striations or bands are found to be rich in respective elements of the alloy, with primary particles also of a form and size consistent with that of the casting microstructure. Computer simulations, with which results obtained in producing castings are in close accord, indicate that a CEP producing such microstructure gives rise to generation of intense pressure waves at a level of about ± 400 MPa in the CEP, and result in separation of alloy elements on the basis of differences in their densities.

The disclosure of each of several of our earlier applications referred to herein is hereby incorporated by reference into, and is to be read as part of the disclosure of the present invention. These applications are WO99/28065 (PCT/AU98/00987), PCT/AU01/01058 and Australian provisional applications PR7214, PR7216, PR7217 and PR7218.

Finally, it is to be understood that various alterations, modifications and/or additions may be introduced into the constructions and arrangements of parts previously described without departing from the spirit or ambit of the invention.

CLAIMS:

1. A device for use in a hot delivery pressure casting machine for pressure casting of a light alloy, wherein the device includes a hollow housing which, from an inlet end to an outlet end of the device, defines a bore for forming at least a part of the length of a metal flow path for the flow of alloy from the outlet of an alloy supply source of the machine to a die cavity defined by a mould or die of the machine; the housing, at the inlet end thereof, is adapted to receive the outlet of the alloy supply source and, at the outlet end thereof, a relatively short portion of the housing is adapted to be neatly received in an opening defined by a cover portion of the mould or die, whereby the bore of the housing enables communication between the supply source and the die cavity; and wherein the device further includes an electric resistance coil, disposed around the housing along a major part of the housing from adjacent the inlet end to the outlet end and connectable to an electric power source, and insulating means around the coil for reducing dissipation of heat energy from the housing and coil and providing control of the heat energy level of the housing and the temperature of alloy flowing through the bore.

2. A device according to claim 1, wherein the bore has inlet and outlet end portions of its length, with the outlet end portion increasing in cross-sectional area to the outlet end from a minimum area defined at or adjacent to the inlet end portion whereby the outlet end portion of the bore defines a controlled expansion port (or CEP) enabling use of the device for direct injection of alloy into a die cavity from the CEP in which the flow velocity of alloy in the CEP decreases relative to its flow velocity in the inlet end portion.

3. A device according to claim 1, wherein the bore is of a form throughout its length which provides an alloy flow velocity rate enabling use of the device for indirect injection into the die cavity via a portion of the flow path defined by the mould or die cover portion and including a runner.

4. A device according to claim 3, wherein the bore is of substantially uniform cross-section throughout its length.

5. A device according to any one of claims 1 to 4, wherein the housing has an external form which is circular in cross-sections taken transversely of the bore.

6. A device according to any one of claims 1 to 5, wherein the bore is circular in cross-sections taken transversely thereof.

7. A device according to any one of claims 1 to 6, wherein the inlet end of the housing defines a seat which is complementary to the outlet end of a supply source, with which the device is to be used, to enable a substantially leak-free flow of alloy from the source to the bore.

8. A device according to any one of claims 1 to 7, wherein the device is adapted to be mounted in relation to a mould or die with which it is to be used, by inserting the housing into the opening of the cover portion of the die or mould to position the outlet of the housing at a required location adjacent to the die cavity.

9. A device according to claim 8, wherein the housing has engagement means at or towards the inlet which is engageable with the cover portion, or with a platen on which the cover portion is mounted, when the outlet of the housing is at the required location.

10. A device according to claim 9, wherein the housing has a lateral abutment adjacent to the inlet which forms the engagement means and is adapted to bear against an external surface of the cover portion or platen when the housing has been fully inserted into the opening to position the housing outlet at the required location.

11. A device according to claim 9, wherein the engagement means includes a lateral abutment extending laterally from the housing and a sleeve concentrically around the housing and against which the abutment bears, and wherein the sleeve is engageable in the cover portion or platen to a

predetermined depth to thereby position the housing outlet at the required location.

12. A device according to claim 11, wherein the sleeve has an end face remote from the housing inlet by which the sleeve is adapted to bear against a reference surface of the cover portion or platen.

13. A device according to claim 11 or claim 12, wherein the sleeve has a peripheral surface by which it is adapted to engage securely with the lower portion or platen.

14. A device according to any one of claims 1 to 13, wherein each of the resistance coil and the insulating means extends around the housing along at least part of the length of the bore.

15. A device according to any one of claims 9 to 13, wherein each of the resistance coil and a heat shield comprising the insulating means extends around the housing from adjacent to the housing outlet to the engagement means.

16. A device according to any one or claims 11 to 13, wherein each of the resistance coil and a heat shield comprising the insulating means extends around the housing from adjacent to the housing inlet, within the sleeve, to define an annular air-gap between the sleeve and each of the housing and the insulating means and thereby minimise thermal contact.

17. A device according to claim 14, wherein the insulating means comprises thermal insulation retained around the housing and the resistance coil by an elongate bush through which the housing extends.

18. A device according to claim 17, wherein one end of the bush terminates at an end portion of the housing which defines the outlet and, wherein said end portion of the housing is adapted to be neatly received in the opening defined

by the cover portion of the mould, and the other end of the bush terminates in an end portion of the housing which defines the inlet.

19. A device according to any one of claims 1 to 18, wherein the housing is adapted for heating adjacent to the inlet to augment heating by the resistance coil.

20. A device according to claim 19, wherein the housing is provided with a heat shield which extends outwardly therearound, for protecting the mould cover portion or platen from said augmenting heating.

21. A hot delivery pressure casting machine, for pressure casting of light alloys, wherein the machine includes a mould or die defining at least one die cavity, a supply source of alloy, and means forming at least part of the length of an alloy flow path from an outlet end of the supply source to the die cavity, and wherein the means forming at least part of the flow path length is a device according to any one of claims 1 to 20.

22. A hot delivery pressure casting machine, for pressure casting of a light alloy, wherein the machine includes a mould or die defining a die cavity, a supply means for supplying alloy and a device located intermediate the supply means and the die or mould; the device includes a hollow housing which, from an inlet end to an outlet end of the device, defines a bore forming at least a part of the length of a metal flow path for the flow of alloy from the outlet of the alloy supply means to the die cavity; the housing, at the inlet end thereof, is coupled to the outlet of the alloy supply source and, at the outlet end thereof, a relatively short portion of the housing is neatly received in an opening defined by a cover portion of the mould or die, whereby the bore of the housing provides communication between the supply source and the die cavity; and wherein the device further includes an electric resistance coil, disposed around the housing along a major part of the housing from adjacent the inlet end to the outlet end and connectable to an electric power source, and insulating means around the coil for reducing dissipation of heat energy from the housing and coil and providing control of the heat energy level of the housing and the temperature of

alloy flowing through the bore; and wherein the bore has inlet and outlet end portions of its length, with the outlet end portion increasing in cross-sectional area to the outlet end from a minimum area defined at or adjacent to the inlet end portion whereby the outlet end portion of the bore defines a controlled expansion port (or CEP) which increases in cross-sectional area to the outlet end and by which the bore opens to the die cavity whereby the device provides for direct injection of alloy into the die cavity from the CEP with a decreased alloy flow velocity in the CEP relative to its flow velocity in the inlet end portion.

23. A hot delivery pressure casting machine, for pressure casting of a light alloy, wherein the machine includes a mould or die defining at least one die cavity, a supply means for supplying alloy and a device located intermediate the supply means and the die or mould; the device includes a hollow housing which, from an inlet end to an outlet end of the device, defines a bore forming a first part of the length of a metal flow path for the flow of alloy from the outlet of the alloy supply means to the die cavity; the housing, at the inlet end thereof, is coupled to the outlet of the alloy supply source and, at the outlet end thereof, a relatively short portion of the housing is neatly received in an opening defined by a cover portion of the mould or die, whereby the bore of the housing provides communication between the supply source and the die cavity; wherein the device further includes an electric resistance coil, disposed around the housing along a major part of the housing from adjacent the inlet end to the outlet end and connectable to an electric power source, and insulating means around the coil for reducing dissipation of heat energy from the housing and coil and providing control of the heat energy level of the housing and the temperature of alloy flowing through the bore; and wherein the bore at an outlet end of the housing opens to a runner forming a second part of the length of the flow path defined by the die or mould, with communication between the runner and the die cavity being provided by a controlled expansion port (or CEP) which increases in cross-sectional area towards the die cavity whereby the flow path provides for indirect injection of alloy into the die cavity from the CEP with a decreased alloy flow rate in the CEP relative to its flow velocity in the runner.

24. A hot delivery pressure casting machine according to any one of claims 21 to 23, wherein said machine is a hot-chamber pressure casting machine and said supply means outlet is defined by a goose-neck nozzle of the machine.

25. A hot delivery pressure casting machine according to any one of claims 21 to 23, wherein said machine is a cold-chamber pressure casting machine and said supply means outlet is defined by a shot-sleeve of the machine.

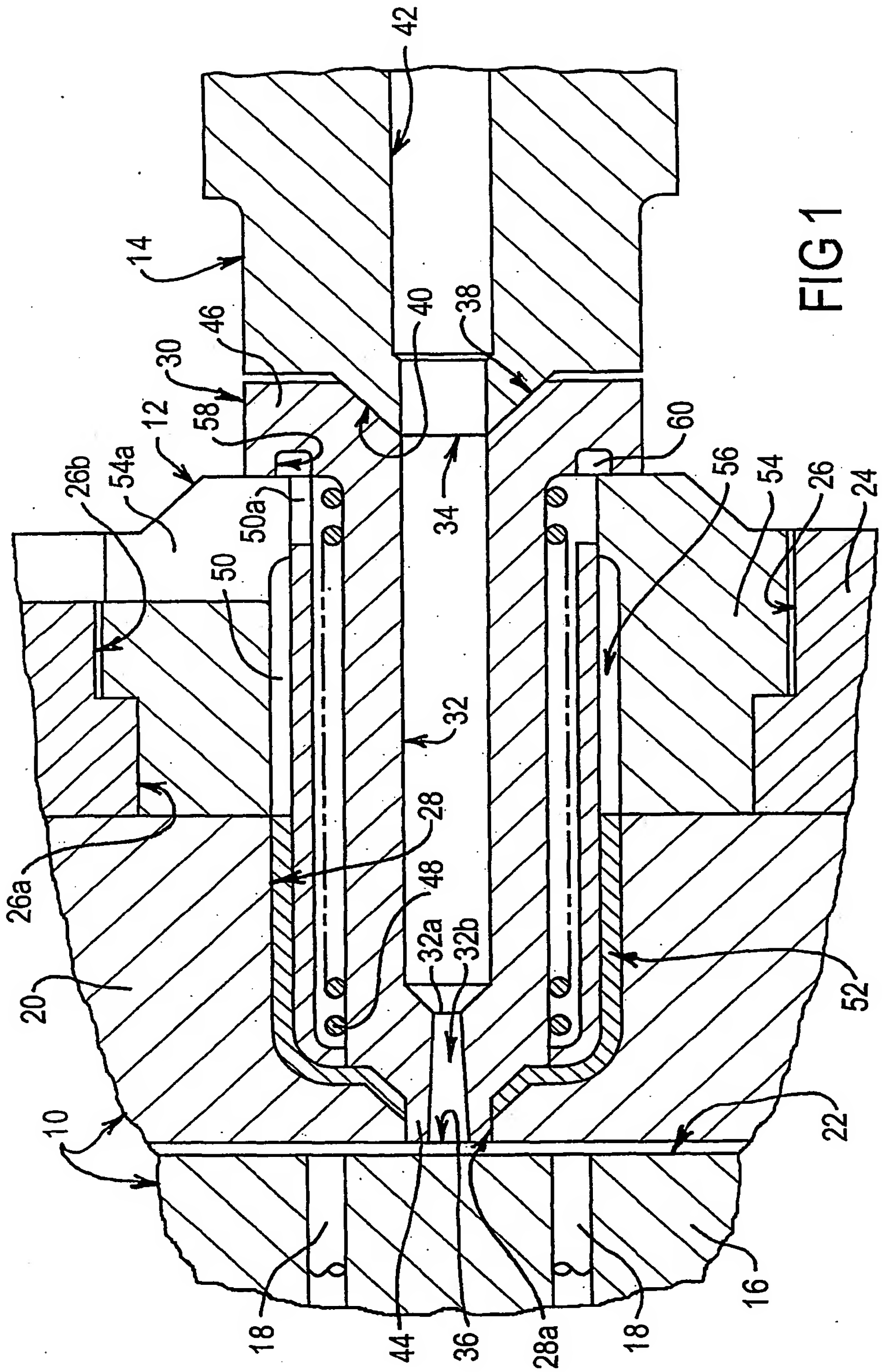
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FIG 1

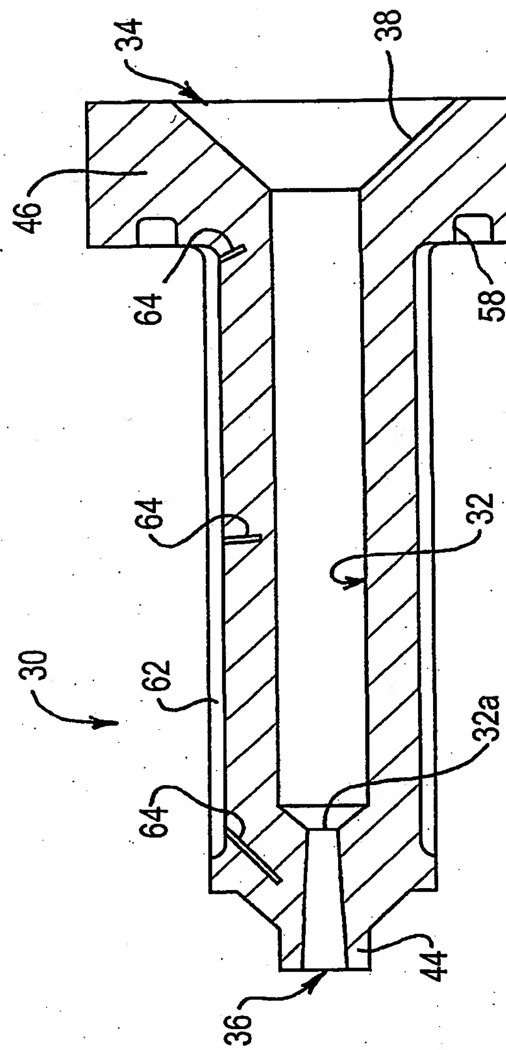

FIG 2

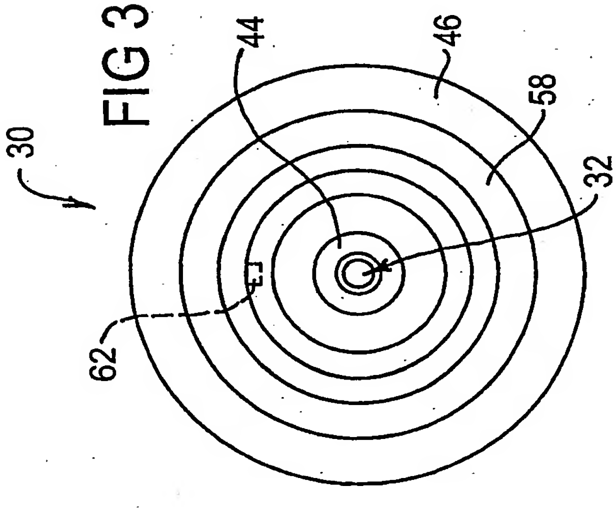

FIG 3

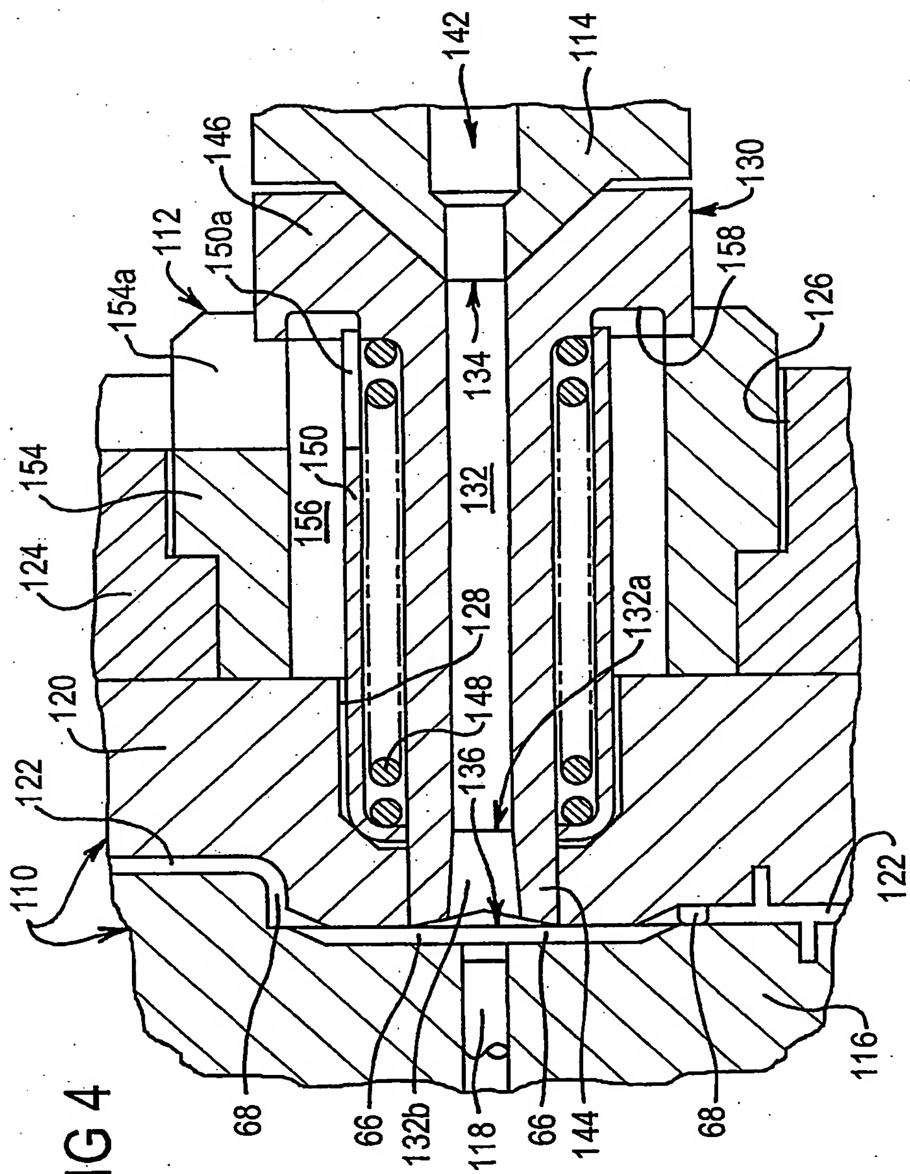
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FIG 4

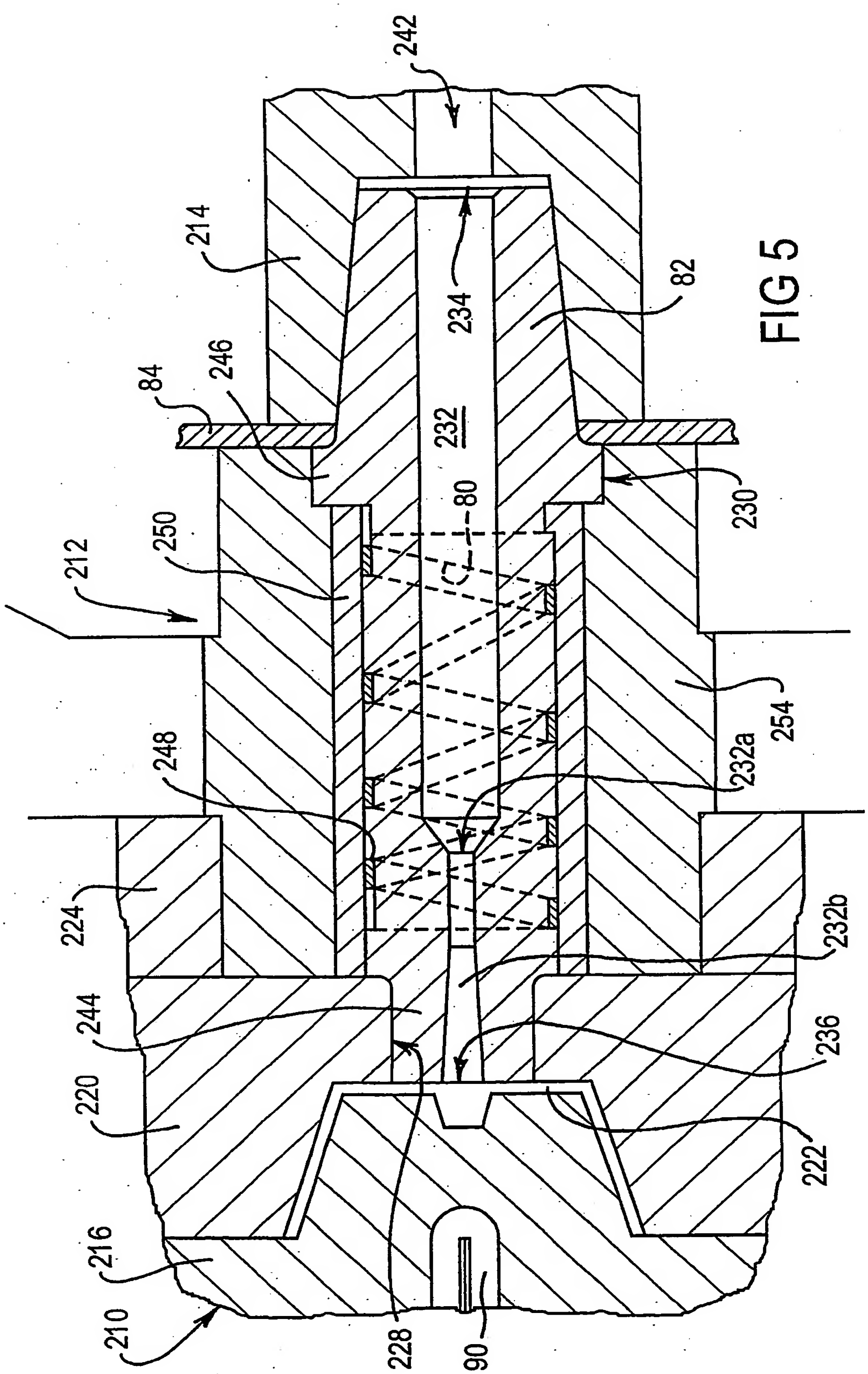
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FIG 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU01/01290

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. [7]: B22D 17/30, 17/00, 21/04, 37/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: B22D 17/IC, 21/IC, 37/IC AND KEYWORDS

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: B22D 17/30, 17/00, 21/04, 37/00

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Derwent:- electric+ or resist+ AND aluminium or magnesium

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, 4638849, A (Whitehorn) 27 January 1987	1,5,6,7,21
A	US, 5203397, A (Bandyopadhyay) 20 April 1993	1-25
A	GB, 2299041, A (Honda Giken Kogyo Kabushiki Kaisha) 25 September 1996	1-25

☐ Further documents are listed in the continuation of Box C ☐ See patent family annex

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 October 2001	- 8 NOV 2001

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU01/01290

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	4638849	NONE					
US	5203397	CA	2084434				
GB	2299041	DE	19611420	FR	2731934	JP	8257725
		US	5872352	JP	8261664	JP	8257728

END OF ANNEX